A NOTE ON SURFACE WIND-SPEED OBSERVATIONS

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ABSTRACT

Hourly surface wind-speed observations recorded over 2 yrs. at 16 Weather Bureau Airport Stations were studied to establish relationships between average daily speeds and the frequencies of individual hourly speeds. Only days with no precipitation were considered. Although the results of the study are intended for use in air pollution meteorology, they are of general interest to synoptic meteorologists.

1. INTRODUCTION

A common meteorological measurement of particular importance in air pollution work is the wind speed near the surface, the "surface" wind speed. The wind speed conducive to high potential for community air pollution is often specified by one or both of two criteria: (1) that the *individual* hourly speeds throughout some period (usually a day) should not exceed a prescribed value, and (2) that the *average* of the hourly speeds throughout the period should not exceed a prescribed value. The latter criterion, especially, is often used in climatological evaluations of air pollution potential, and is given as the number of days during which the average daily speed was less than a specified value. In some climatological studies the frequency of subcritical average daily speeds is implied from average monthly speeds.

The purpose of this study is to inquire into the relationships between average daily (0100–2400 LST observations) wind speeds and individual hourly wind speeds observed during corresponding 24-hr. periods. The results of the study have useful applications in air pollution meteorology and in other meteorological fields as well. An unintended revelation of the study is observer bias for certain speeds.

2. DATA AND TABULATIONS

Regular hourly wind-speed observations recorded during 2 yr. (1962 and 1963) at 16 Weather Bureau Airport Stations distributed over the contiguous United States were utilized for this study. Wind-speed observations at Weather Bureau Airport Stations are commonly made by sight-averaging the values indicated by a pointer over about 1 min. The sensing instruments were standard Weather Bureau anemometers located on the airfields; at most stations the instruments were positioned 20 ft. above the ground, but at others the heights varied between 18 and 24 ft.[2] The stations selected for study are listed in table 1.

TABLE 1.—*Weather Bureau Airport Stations for which wind-speed tabulations were obtained. The heights of anemometers at other than 20 ft, above the surface are given in parentheses*

Athens, Ga.—Clarke County Airport	Providence, R.I.—T. F. Green Airport
Chicago, Ill.—Midway Airport	Salem, Oreg.—McNary Field
Dallas, Tex.—Love Field	Salt Lake City, Utah—Municipal Airport
Denver, Colo.—Stapleton Field	San Francisco, Calif.—International Airport
Los Angeles, Calif.—International Airport (21 ft.)	Seattle, Wash.—Seattle-Tacoma Airport
Miami, Fla.—International Airport (23 ft.)	Sioux City, Iowa—Municipal Airport (24 ft.)
New Orleans, La.—Moisant Airport	St. Louis, Mo.—Lambert Field
Phoenix, Ariz.—Sky Harbor Airport (18 ft.)	Washington, D.C.—National Airport

For each station and for all 16 stations together machine tabulations of the percent frequency of individual hourly wind speeds, according to average daily speeds, were prepared by the National Weather Records Center (NWRC).[3] Individual hourly speeds were grouped in whole 1-kt. intervals (as observed) through 20 kt., with all greater speeds classed as 20+. Average daily speeds were grouped in intervals of 1 kt. by tenths (e.g., 4.1–5.0, 5.1–6.0, etc.) through 10.0 kt., except that the lowest-speed group included all average speeds of 4.0 kt. or less. Since high meteorological potential for community air pollution seldom occurs on days with precipitation, wind data for such days were excluded from the tabulations.

3. DISCUSSION

For each average daily wind-speed group the percent frequency of individual hourly wind speeds is graphed in figure 1. The heavy continuous curves connecting the large dots represent values for all 16 stations combined. The lower and upper lightly dashed curves connecting the small dots represent the lowest and highest percentage frequencies that occurred at any of the 16 stations. Zero frequencies are not plotted. Although individual graphs for each of the 16 stations are not presented here, comparison showed that the general features and many

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[2] Since about 1960 wind equipment at most Weather Bureau Airport Stations has been located on the airfields and preferably 20 ft. above the ground.

[3] Copies of these tabulations may be obtained at nominal cost by request to the Director National Weather Records Center, Asheville, N.C. Refer to Job No. 5697, "Average Daily Wind Speed vs. Hourly Wind Speed," dated June 3, 1964.

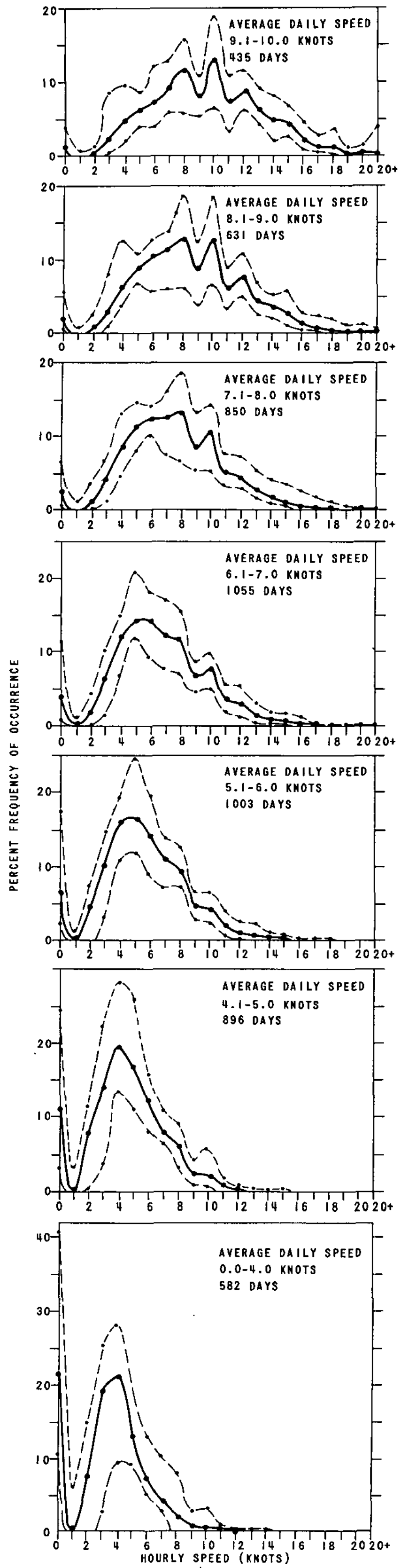

FIGURE 1.—Percent frequencies of hourly surface wind speeds by average daily speeds for non-precipitation days in 1962 and 1963. Heavy continuous curves represent all 16 stations (see table 1) combined. Lower and upper dashed curves represent the lowest and highest percentage frequencies at any of the 16 stations. Zero frequencies are not plotted.

details of the separate curves for each station were quite similar to the curves for all stations combined. This was true even for those stations that contributed only a relatively few days to the total for a particular graph. The similarities among the separate stations are borne out in figure 1, in which the range curves are very much like the corresponding curves for all stations combined.

An outstanding and unexpected characteristic of the curves in figure 1 is their irregular configuration over certain portions of the range of individual hourly speeds. This irregularity is most noticeable at higher average daily speeds and over the hourly speed range of 8 through 12 kt. For example, the curve for average daily speeds of 9.1–10.0 kt. exhibits a disproportionately high frequency of 8-, 10-, and 12-kt. hourly speeds and a disproportionately low frequency of 9- and 11-kt. hourly speeds. On the same curve, but much less pronounced, is a slight excess in the frequencies of 15-, 18-, and 20-kt. individual speeds. This high incidence of certain reported speeds is attributed to observer bias in sight-averaging the wind-speed fluctuations over 1 min. The bias is more manifest on those graphs on which the preferred speeds occur more frequently. Thus, the preference for 10-kt. individual speeds is barely perceptible on the graph for average daily speeds of 4.0 kt. or less, but is readily apparent, together with a bias for 8-kt. speeds, on the graph for average daily speeds of 4.1–5.0 kt. The bias for 12-kt. individual speeds first becomes manifest at average daily speeds of 6.1–7.0 kt.; for 15-kt. individual speeds, at average daily speeds of 8.1–9.0 kt.; and for 18- and 20-kt. individual speeds, at average daily speeds of 9.1–10.0 kt. The bias over the range of individual speeds of 8 through 12 kt. was readily apparent for each of the 16 stations. The bias for 15-, 18-, and 20-kt. speeds was detectable for all but a few of the stations. Apparently, the phenomenon of observer bias for certain wind speeds is widespread.

Other outstanding features of the curves in figure 1, especially for low average daily speeds, are the relatively high frequencies of calms and the low frequencies of 1-kt. and, to a lesser degree, 2-kt. individual speeds. These features are due largely to the lack of anemometer response at speeds less than about 3 kt. As a result, reported average daily speeds are lower than the real average daily speeds. This difference is usually greater for reported low average daily speeds than for reported high average daily speeds. All except two of the 16 stations displayed relatively high frequencies of calms, zero frequencies of 1-kt. speeds, and relatively low frequencies of 2-kt. speeds. Washington, D.C., was the only station that reported more than a very few 1-kt. speeds, which appear to have been reported at the expense of calms. Investigation of this anomaly disclosed that for 18 of the 24 months of data tabulated for Washington, D.C., an Automatic Meteorological Observing Station (AMOS) was in operation. This equipment readily detected 1- and 2-kt. wind speeds. It is interesting that although only about one-fourth of the Washington, D.C.,

TABLE 2.—*Percent of hourly wind speeds that exceeded the indicated hourly speeds, according to average daily speeds. Data are for all 16 stations combined.*

Average daily speed (kt.)	Hourly speed (kt.)					
	5	6	7	8	9	10
0.0–4.0	15.8	8.2	3.9	1.6	0.7	0.2
4.1–5.0	33.0	20.5	12.2	6.2	3.7	1.5
5.1–6.0	47.6	33.5	22.6	13.2	8.4	4.1
6.1–7.0	61.7	47.7	35.5	23.7	16.9	9.4
7.1–8.0	72.6	60.4	48.2	35.1	26.6	16.3
8.1–9.0	80.5	70.5	59.5	46.9	38.5	26.2
9.1–10.0	85.7	78.5	69.5	57.9	50.1	37.1

wind speeds were determined by the sight-averaging method, observer bias for certain speeds could still be detected. The bias was somewhat less striking, however, than at the other stations. Providence, R.I., on the other hand, in addition to reporting no 1-kt. speeds, reported much the lowest frequencies of 2- and 3-kt. speeds, which appears to have greatly enhanced the reported occurrence of calms.

Figure 1 shows that as the average daily wind speeds increase (through successive graphs) the ranges of hourly speeds increase, the modal hourly speeds increase, and the modal frequencies decrease. Consequently, for higher average daily speeds the curves are flatter.

In the national program of air pollution potential forecasting, conducted at the Weather Bureau Research Station, Cincinnati, Ohio [1, 2, 3], one of the forecast criteria has been that surface wind speeds reported in hourly observations should not exceed 7 kt. during a 24-hr. day. To facilitate forecast verification the wind-speed criterion was assumed to be satisfied whenever the average daily speed was 5.0 kt. or less. According to table 2, however, when the average daily speed was 4.1–5.0 kt., near the upper limit for verification, hourly speeds exceeding 7 kt. occurred about 12 percent of the time (in 3 of the 24 hourly observations). For stations that have been included in forecast areas of high air pollution potential many of the average daily speeds were in the range of 4.1–5.0 kt. Consequently, in such cases it is unlikely that the criterion of no hourly speeds greater than 7 kt. was met. In spite of this inconsistency national air pollution potential forecasts have been well verified by air quality data [1, 2, 3]. On practical grounds the specification of an hourly wind speed that is likely to be approached, but should not be exceeded during 24 hr., is not reasonable, as indicated by figure 1 and table 2. In view of the foregoing discussion, reasonable wind-speed criteria (for anemometers near 20 ft. above the ground) for forecasts of high air pollution potential are as follows: (A) the average daily wind speed should not exceed 5.0 kt., or (B) of the 24 observations during a day, hourly wind speeds greater than 7 kt. should not be observed more than three times. These criteria have been incorporated into the national program of air pollution potential forecasting.

Although data for some days (days on which no precipitation occurred) not conducive to high meteorological potential for community air pollution were eliminated from the tabulations, it is likely that data are included for some such days that would be excluded by other forecast criteria. Experience suggests that the effect of restricting the wind-speed tabulations to those days when other forecast criteria were met would be to eliminate days with higher average speeds. It is speculated, however, that for sufficiently low average daily speeds the general features of the curves in figure 1 would not be altered significantly.

The specified wind speed criteria (A and B) are intended for use in the national program of air pollution potential forecasting, which evaluates certain meteorological dispersion parameters on a synoptic scale. The forecasts are considered to be only more or less applicable to different communities because among other things the critical values of the dispersion parameters are not permitted to vary among different communities. For example, considering a set of values of meteorological dispersion parameters for a community, the realization of pollutant concentrations above some given value will depend not only on the emission rate of pollutants per unit area, but also upon the total area over which the emissions take place. Very briefly, this is, of course, because each source area upwind of a receptor contributes to the atmospheric pollutant concentrations at the receptor. Consequently, other things being the same, in different-sized communities the occurrence of air pollutant concentrations above a given value depends upon different values of the meteorological dispersion parameters. Generally, the appropriate different values of the dispersion parameters are a function of the overall sizes of the various communities (source areas). Consideration of appropriate values of the dispersion parameters for individual communities is beyond the scope of the national program of air pollution potential forecasting. The utility of the forecasts can be enhanced, however, by evaluating such details at the level of the local user. For this purpose, and especially in climatological studies of air pollution potential, the data of figure 1 and table 2 will be useful.

SUMMARY

The information presented has established relationships between average daily surface wind speeds and the individual hourly observations upon which the daily averages are based. These relationships are consistent among the 16 stations considered, and provide a basis for the specification of wind-speed criteria for the national program of air pollution potential forecasting. An unexpected revelation of the study is observer bias for certain wind speeds, especially 8, 10, and 12 kt.

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